Progress on the revision of the Iberian sardine assessment for the benchmark

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Abstract

This working document presents work progress on the revision of the assessment model of the Iberian sardine. Data and model exploration were carried out to address some of the issues outlined in the last sardine benchmark in 2012. Specifically, we address assumptions about initial equilibrium catch, recruitment modelling and time varying selectivity. The aim is to promote discussion in WGHANSA 2016 and to define guidelines for further work to be undertaken until the benchmark assessment scheduled for early 2017.

Introduction

In the last benchmark (ICES 2012), some of the topics outlined for further work to improve the assessment model where:

. initial equilibrium catch

. recruitment assumptions.

. time-varying selectivity

Reviewers commented on two main topics: the need to look at the implication of allowing dome selectivity in the fishery and in the acoustic survey and the implications of the “disconnect” in the acoustics and DEPM surveys while assuming equal survey variances to weight them within the model.

Since then, another issue has been raised which appears to be related to selectivity assumptions: unrealistic confidence intervals for fishing mortality in the early assessment period (1978-1990). This issue was explored in WGHANSA 2014 (ICES 2014). The work carried out indicated that extending the assumption of time-varying selectivity to the whole assessment period eliminated the sharp increase in fishing mortality confidence intervals prior to 1991. The results suggest the assumption of fixed selectivity from 1991 up to the present has become too rigid because the real selectivity is possibly varying over time.

This working document presents results of data and model exploration to address assumptions about initial equilibrium catch, recruitment and time varying selectivity. The objective is to have a starting point for discussion in WGHANSA 2016 to assist the definition of further work to be undertaken until the benchmark assessment scheduled for early 2017.

Data and methods

Catch and survey data cover the period 1991-2015 and were assembled from area- and quarter- disaggregated data reported to the assessment Working Groups since 1991. There are some differences between total stock catch- and abundance-at-age as used in the assessment and total stock catch- and abundance-at-age pooled from area-quarter disaggregated data as used in this exercise. The differences are, however, small: below 4% for surveys (abundance-at-age-year) except for 1996 and 2011 (see below), and below 3% for catches-at-age except in 1997 (age 0: - 8.4% and age 1: 7.8%, reason unclear).

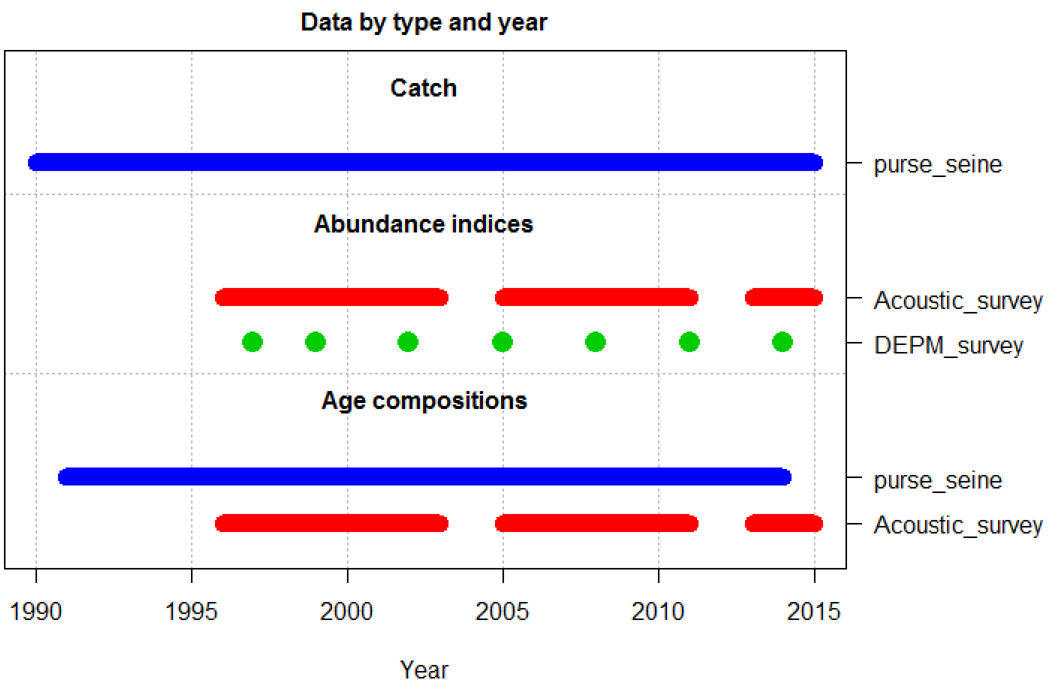
Differences in two surveys are due to:

- correction to the PELAGO 1996 abundances-at-age: ALKs for npor and swpor were very poor, did not represent the length distributions within ages, causing unreasonably low 6+ abundance which creates a high residual in all assessments. ALKs from port sampling in the same areas were pooled with survey ALKs to calculate abundance-at-age. Corrected estimates for ages 1-4 are similar to old ones (differences<6%) but abundances at ages 5 and 6+ increase 47% and 60% respectively;

- correction to the PELAGO 2011 abundance at age: two problems were found, fish below 10 cm in npor (age 1) were not accounted for because otoliths were not read; in addition, a mistake was found in the application of ALKs. Overall % differences of new abundance estimates relative to old ones are +22.3, +2.8, -15.6, -5.2, -1.4,-2.6, for ages 1 to 6+ respectively.

In all model settings, numbers are in thousands, biomass in tons and weight in kg.

SS3 version 3.24f (Methot and Wetzel, 2013) and the R r4ss (Taylor et al. 2015) were used in the analyses and presentation of results, respectively.



1. Initial population (initial equilibrium catch)

In SS3 there are three approaches to estimate the population in the initial year (the year before the first year in the assessment), assuming:

(a) the initial population is an unfished equilibrium population; therefore initial N-at-age are derived from R0, the maximum R level applying only M {N0,a=R0*exp(-Ma)};

(b) the initial population is an equilibrium population subject to fishing mortality: fishing mortality is derived from an assumed equilibrium catch which is input to the model, and selectivity in the first year (CURRENT METHOD)

(c) the initial population deviates from the equilibrium; in this case, the model estimates age-specific deviations from the expected equilibrium for a number of years before the start of the assessment period. The procedure is similar to projecting the cohorts backwards in time from the first year, using only natural mortality. Early recruitment deviations are estimated by comparing their projected abundance at age 0 with R0. If the number of age-specific deviations in the initial age composition is less than the total number of age groups in the model then the older ages will retain their equilibrium levels. In addition, an offset parameter can be estimated for the initial year which sets how much recruitment in that year differs from R0.

In the current assessment, the initial equilibrium catch is set at 100 000 tons, the "recent level of catches" at the time of the 2012 benchmark. The sensitivity of the assessment to this assumption was not presented in the last benchmark.

Here, we explored this assumption by trying values from 30 000 t to 80 000 t, checking the fit of the model and SSB estimates at the first and last assessment years. Changes in initial equilibrium catch have a major effect on the assessment, by changing the old vs recent fishing mortality/biomass of the stock: the higher the initial equilibrium catch the higher is the old vs recent fishing mortality and the lower is the old vs recent biomass (Table 1).

Table 1 – Changes in model Log-likelihood and initial and final SSB estimates as a function of the initial equilibrium catch (in thousand tons).

Initial equilibrium catch	Log Lik	SSB 1991	SSB 2015	
30	144.2	413	115	Base Model 1991-2015 (mimic 2015 assessment)
40	144.9	371	118	
50	146.6	333	123	
60	149.3	305	132	
70	153.2	287	147	
80	158.5	281	170	
100		483	129	2015 assessment

The approach (c) explained above was then applied: the estimation of early recruitment deviations was started in 1985 (i.e., projecting ages 1 to 6+ backwards) to get the initial population. The Base Model with similar assumptions to the 2015 assessment and an initial equilibrium catch of 40 000 t was run for comparison. The model early recruitment deviations to estimate the initial population provided a better fit to the data mainly due to the better fit to age compositions (Table 2). The summary results were similar to those from the 2015 assessment (Figure 1).

Table 2 – Likelihood components, estimated quantities and AIC comparing models (1) Base Model with equilibrium catch= 40 000 t and (2) Model with 6 early R deviations.

Label	Base Model with Eq.Catch=40 000 t	Model with 6 early R deviations
TOTAL	144.96	136.84
Catch	4.56E-08	4.36E-08
Equil_catch	0.03	0.00
Survey	-4.63	-5.40
Age_comp	130.33	120.27
Recruitment	19.24	21.98
SPB_Virgin_thousand_mt	271.57	270.25
SPRratio_2014	0.47	0.49
Number parameters	33	38
Maximum gradient	1.4E-05	4.5E-05
AIC	355.9	349.7

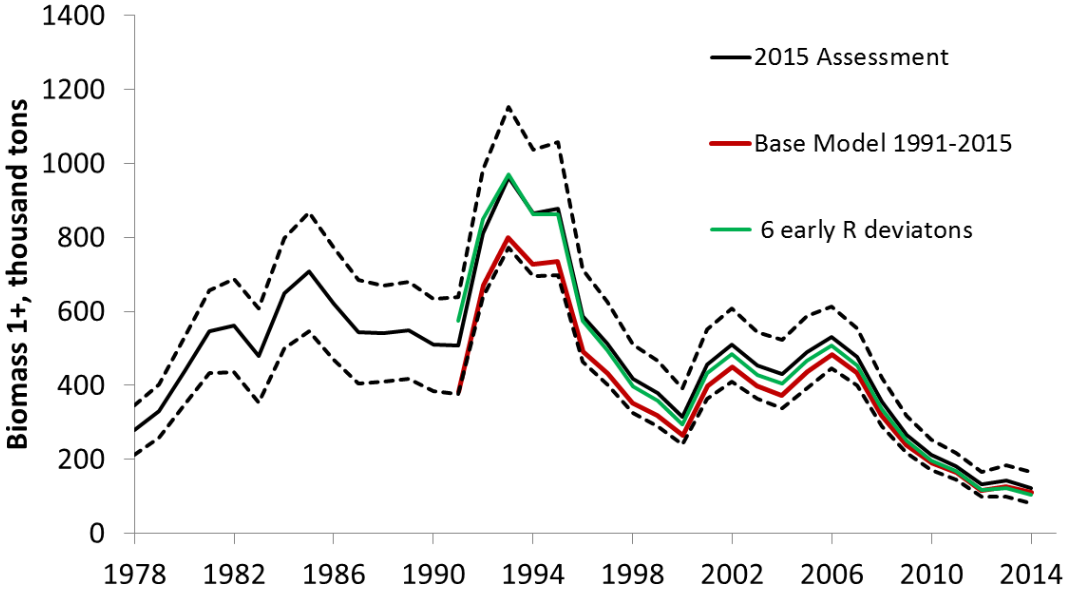


Figure 1 – Biomass 1+ estimated in the 2015 assessment, in a similar model for 1991-2015 (with equilibrium catch=40 000 t) and in the model using age-specific deviations to estimate the initial population.

2. Recruitment

In the current sardine assessment recruitment is assumed to be independent of spawning biomass at all SSB levels. Maximum recruitment is estimated within the model by the geometric mean recruitment of the historical series (R0). On top of this stock-recruitment relationship, yearly deviations from R0 are allowed with a standard deviation of 0.55 (input standard deviation of recruitment deviations on a log scale). In recent years we have seen historically low levels of biomass producing only low recruitments. The current assessment underestimates both the total acoustic index and age 1 abundance in recent years. Using a stock-recruitment relationship which accounts for density-dependent recruitment at low levels of biomass, such as the Ricker, Beverton-Holt or Hockey stick, is expected to improve the assessment. In SS3, stock-recruitment models are parameterised in terms of *R0* (maximum recruitment) and steepness (*h*). Sigma, the standard deviation among recruitment deviations in log space is usually input.

To obtain preliminary information to parameterise/set initial values for the stock-recruitment relationship within SS3, we explored data from the joint Spanish and Portuguese spring acoustic survey 1996-2015 (gaps in 2004 and 2012). Biomass 1+ in survey year *y* was related to abundance of age 1 individuals in year *y+1*. In total, 15 pairs of stock-recruitment data were available.

Ricker { R=a*B1+*exp(-b*B1+) } and Beverton and Holt { R=a*B1+/(b+B1+) } models were fit to survey data by nonlinear regression. Estimates of the slope near the origin for each model provide information on the steepness of each model in comparative terms. It is also possible to derive a proxy value for sigma (i.e. standard deviation among recruitment deviations from fitted model in log space).

Residual sum of squares were slightly lower for the Ricker model (2.8E+14) than for the B-H model (2.97E+14) (Figure 2). For both models, parameters were not significant at 5% level, residuals were non-normal and were independent (no autocorrelation found). Formal comparison tests between the two models are not applicable due to violation of normality and (possibly) variance homogeneity assumptions.

Slope at origin estimates were:

Ricker: 39.1 recruits/B1+ , 95% asymptotic confidence interval [-13.9, 92.1]

B-H: 47.4 recruits/B1+, 95% asymptotic confidence interval [-110.1, 204.9]

Steepness information from Myers et al, 1999 for clupeidae (using the Ricker model): median=0.71, 20% quantile=0.49, 80% quantile=0.86.

Sigma estimates from each model were almost identical: Ricker- 0.74, B-H: 0.75.

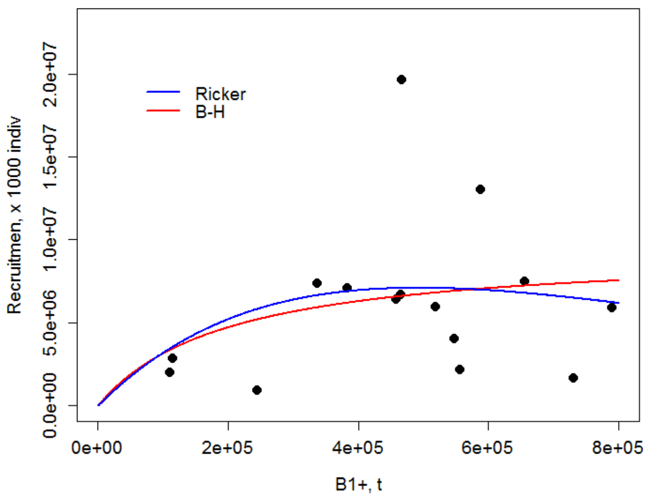
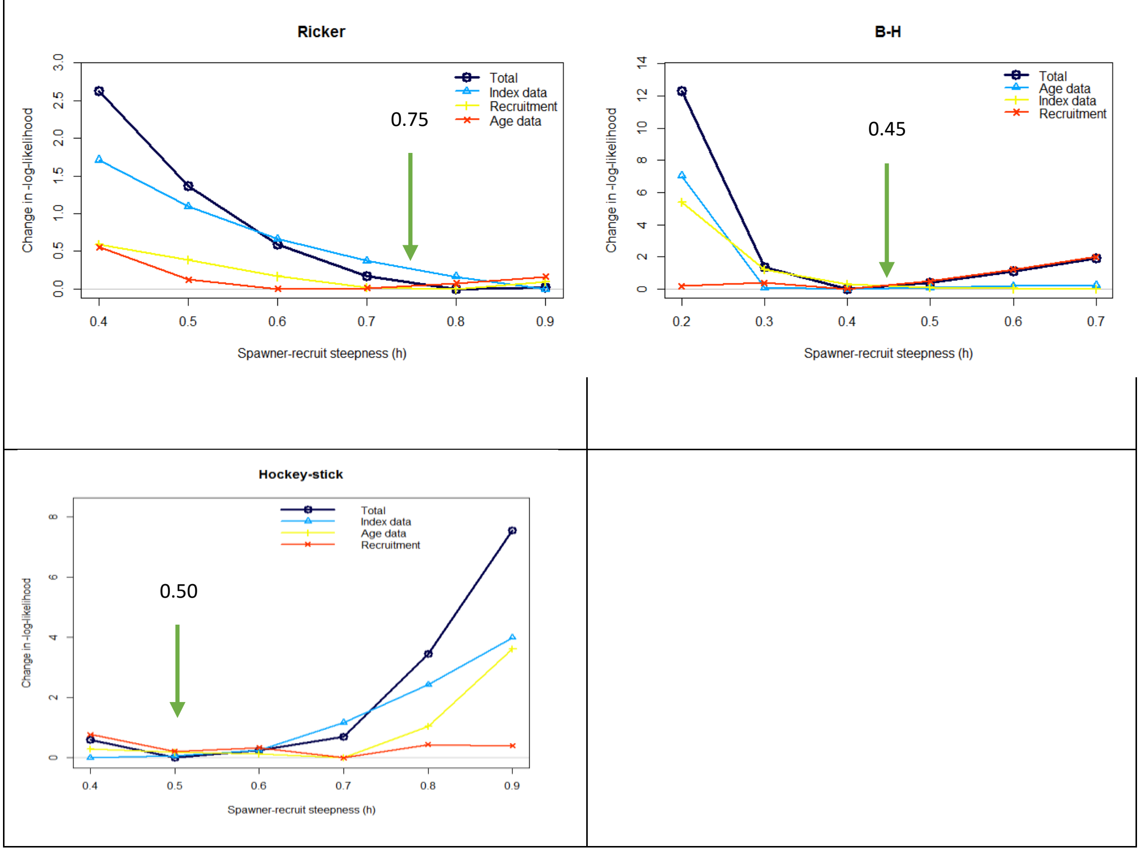


Figure 2 – Ricker and Beverton-Holt models fit to data from the joint Spanish and Portuguese spring acoustic survey 1996-2015.

SS3 runs including the estimation of Ricker, Beverton-Holt and Hockey stick models were carried out. The initial R0 value was set to 8886111 thousand individuals in all runs. A sigma=0.74 was input. Autocorrelation was assumed to be zero. Likelihood profiles were performed for steepness for all models (Figure 3),

Fig 3 . LOG-LIKELIHOOD PROFILE FOR STEEPNESS



The choice of final steepness values resulted from a compromise between the likelihood profile analyses and convergence criteria (<0.0001). In some cases, the steepness estimate at the apparent minimum Log-likelihood resulted in poor convergence.

To compare models, steepness was input as: Ricker=0.75, B-H= 0.45 and Hockey= 0.50. These models were compared with the Early R deviations model obtained above, which assumes recruitment is independent of stock biomass (as in the 2015 assessment).

Table 3 - Comparison of SS3 models including a stock-recruitment model with the Base Run model.

Label	R independent of SSB (Early R deviations Model)	Ricker	BH	Hockey
TOTAL	136.84	122.5	122.6	122.6
Survey	-5.40	-5.7	-5.9	-6.2
Age_comp	120.27	119.2	119.3	119.5
Recruitment	21.98	8.9	9.2	9.3
SPB_Virgin_thousand_mt	270.25	429.2	364.9	331.1
SPRratio_2014	0.49	0.53	0.53	0.53
Number parameters	38	39.0	39.0	39.0
Maximum gradient	4.5E-05	3.79E-05	9.24E-05	3.70E-06
AIC	349.7	322.97	323.16	323.16

The three stock-recruitment models result in very similar fits and reveal a substantial improve in AIC compared to Early R deviations model mainly due to a better estimation of recruitment deviations (Table 3). As a result they fit better to the acoustic index both at high values and at low recent values. These appears to come at the cost of an even poorer fit to the DEPM survey index.

The Early R deviations model has an assumed sigma R of 0.55 while the other models have sigma R=0.74. A test increasing sigma R to 0.75 in the former model did not make any difference.

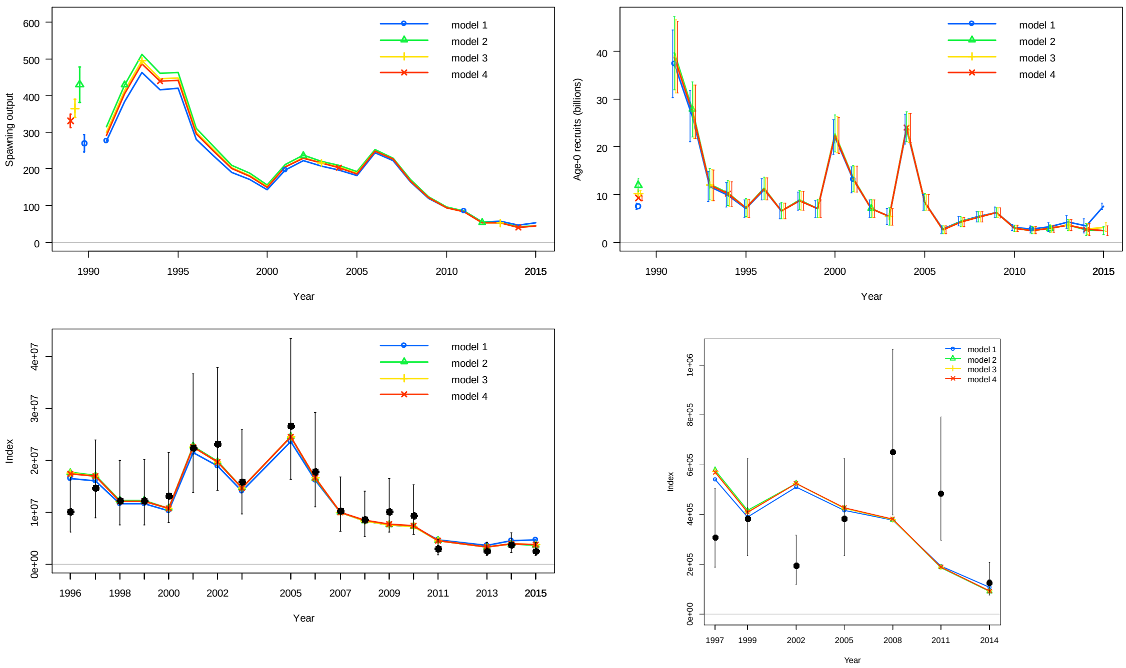


Figure 4 – Model summaries and fits to survey indices. Model1: R independent of SSB (Age-specific deviations model), Model 2: Ricker, Model 3: B-H, Model 4: Hockey stick .

Finally, a model run was carried out using the Ricker model and adjusting for bias in estimates of early recruitment deviations. The number of early recruitment deviations was 5 in this case meaning that the model was started in 1987. Because the older ages in the initial age composition will have progressively less information from which to estimate their true deviation, a bias adjustment ramp should be set (Taylor and Methot, 2011; Methot and Wetzel, 2013). In this model a “bias ramp” was used starting at 0.1 in 1987 and increasing linearly to 1 in 1996, when survey age compositions start. The bias adjusted model showed a lower AIC again mainly due to a better estimation of recruitment deviations (Table 4). The SSB is scaled upwards in the earlier years and the discrepancy decreases towards recent years (Figure 5). The fit to survey indices is similar.

Table 4 - Comparison of SS3 models with and without bias-adjustment ramp. In both cases, the Ricker model is used.

Label	Ricker (5 early R deviations)	Ricker with bias adjustment ramp
TOTAL	122.9	118.7
Survey	-5.3	-3.9
Age_comp	119.4	120.3
Recruitment	8.9	2.4
SPB_Virgin_thousand_mt	419.9	781.5
SPRratio_2014	0.1	0.1
Number parameters	38	38
Maximum gradient	7.7E-05	1.5E-06
AIC	321.9	313.4

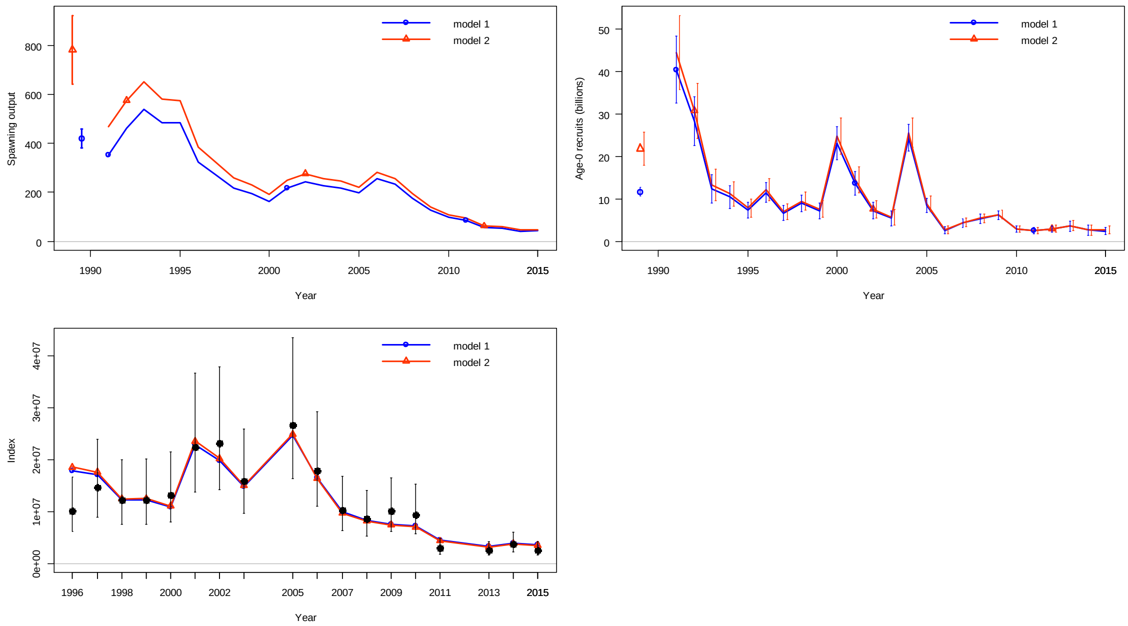


Figure 5 – Model summaries and fits to the acoustic survey index. Model1: Ricker, Model 2: Ricker with bias-adjustment ramp starting at 0.1 in 1987 and increasing linearly to 1 in 1996.

3. Age composition of catches and surveys

a. Time varying selectivity in the Iberian stock

Two forms of selectivity may be considered (Sampson 2014): (a) contact or gear selectivity, results from the fact that not all fish that directly encounter fishing gear are caught and retained by the gear due to e.g. avoidance of the gear, behavioural traits or physical sorting by size; (b) availability is due to the possible differential availability of fish to the fishery due to e.g. geographic heterogeneity in the distribution of the fishery relative to that of the fish, targeting behaviour of the fishery of certain fish sizes. Population selectivity reflects the combination of the other two forms of selectivity, integrated across the entire spatial region occupied by the fish stock. Population selectivity, also termed fishery selectivity, is the selection process relevant to assessing and understanding a stock's dynamics.

To explore the assumption of time-varying fishery selectivity, we looked at a proxy of population selectivity: the ratio between catch and abundance (in numbers) over time for the whole stock (Waterhouse et al. 2014). The period 1996 -2014, for which both catch and acoustic data are available, was divided into 3 sub-periods: 1996-2000 (first fishery crisis), 2001-2008 (stock recovery and stabilization), 2009-2014 (second fishery crisis). The catch/abundance ratio suggests selectivity may have changed in the most recent period, 2009-2014, towards higher selectivity of ages 2+ in comparison to age 1 selectivity (Figure 6). Such a change is consistent with the maintenance of catch levels of ages 2+ (targeting by the fishery) while the population consist almost only of age 1 individuals (Figure 7).

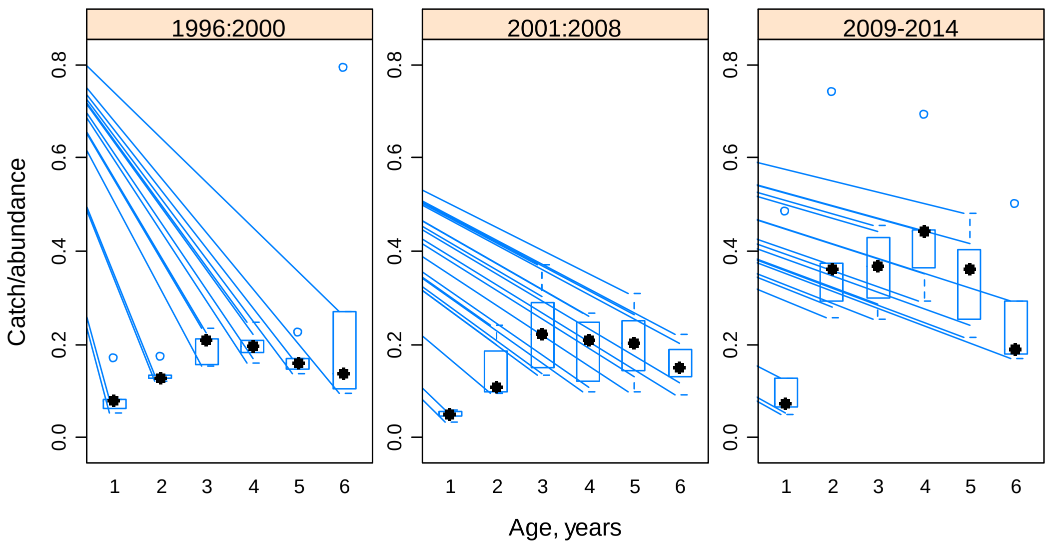
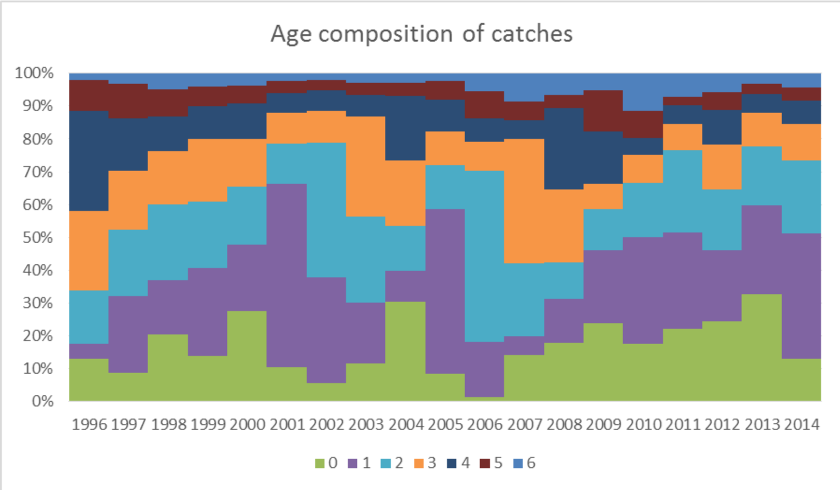


Figure 6 – Ratio of catch/abundance (in number of individuals) for the Iberian sardine stock.



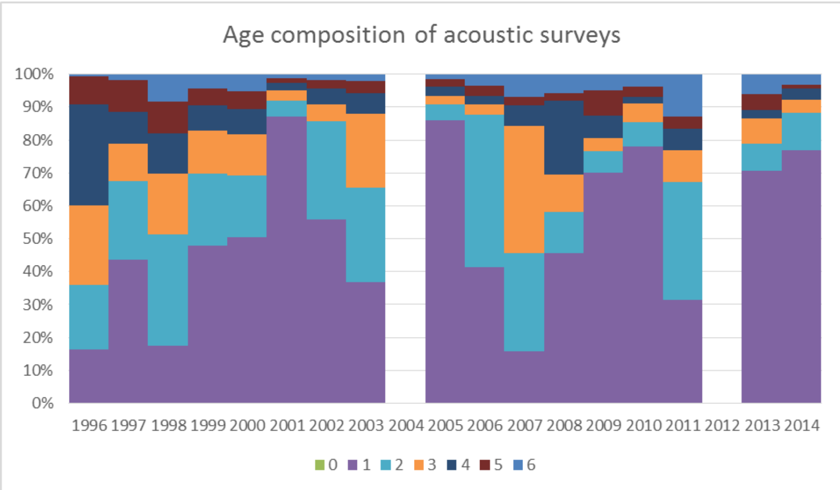
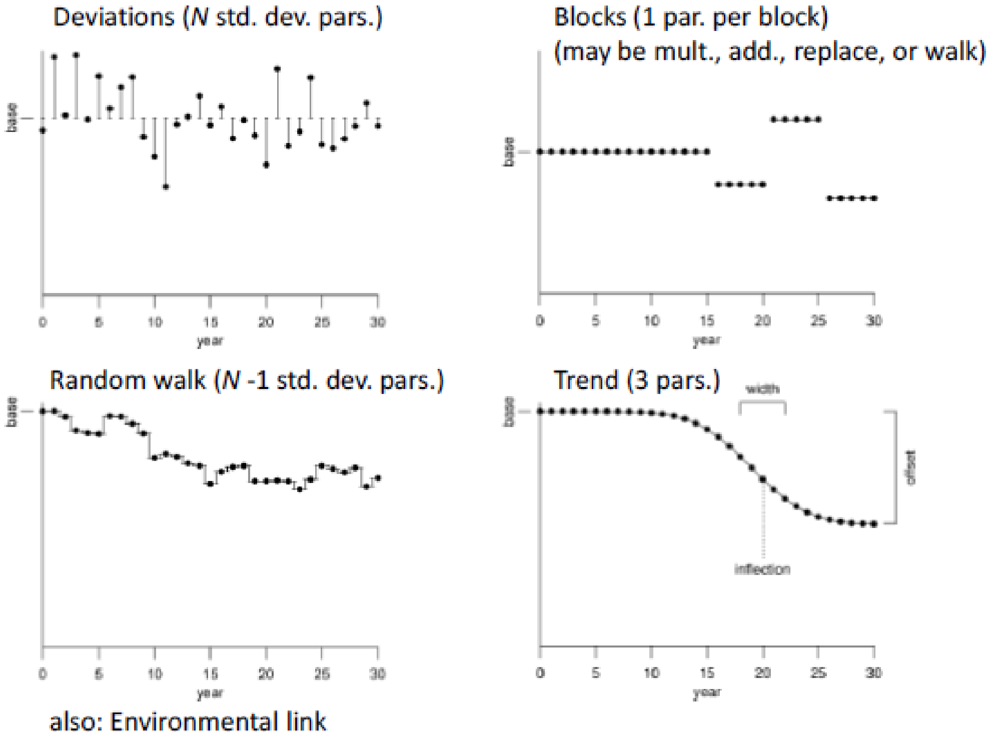


Figure 7 – Age composition of catches and surveys in 1996 – 2014.

In the current sardine assessment, the fishery selectivity is allowed to vary over time in part of the assessment period (ICES 2012). Two periods are considered: 1978-1990 with selectivity-at-age varying as a random walk and 1991-2010 for which selectivity-at-age is fixed over time. In the random walk, log(Sy) = log(Sy-1 + delta(y)), with SD=0.1 as the penalty on the deltas, y being the year). The assumption of fixed selectivity from 1991 up to the present may be too rigid as shown by a systematic pattern of positive residuals at age 0 for the fishery age composition (Figure 8).

In SS3 there are four options for time-varying parameters (selectivity and biology): annual deviations (including random walk), blocks, trend and environmental linkage:



Here, we explored two alternative options to the Early R deviations model which assumes constant selectivity at age over the whole assessment period, 1991-2014. One alternative model considers a random walk in selectivity parameters (with an SD=0.1) through the whole assessment period (1991-2015) and the other alternative model considers two periods with different selectivity (blocks), 1991-2007 and 2008-2014.

Table 5 - Comparison of SS3 models with alternative assumptions about selectivity variation over time. In all cases, recruitment is modelled as annual deviations starting five years before the first assessment year and no bias-adjustment.

Label	Constant selectivity over time (Early R deviations Model)	Time-Varying Sel (random walk, SD=0.1)	Time-Varying Sel by period (1991-2007, 2008-2014)
TOTAL	136.8	130.0	124.2
Survey	-5.4	-7.2	-9.2
Age_comp	120.3	109.4	111.9
Recruitment	22.0	22.0	21.5
SPB_Virgin_thousand_mt	270.3	305.3	268.7
SPRratio_2014	0.49	0.53	0.47
Number parameters	38	109	42
Maximum gradient	4.5E-05	8.4E-05	4.1E-05
AIC	349.7	477.9	332.5

The results indicate the models assuming time-varying selectivity fit better to the catch age composition and eliminate the systematic pattern of residuals in recent years (Table 5, Figure 8). The assumption of smooth variation in selectivity implies a large number of parameters resulting in a higher AIC than the model with constant selectivity over time. This does not happen with the model with two selectivity periods which would be the selected model of the three. The abrupt shift in selectivity between periods looks unrealistic taking into account the data. A gradual change in selectivity could be explored using a trend.

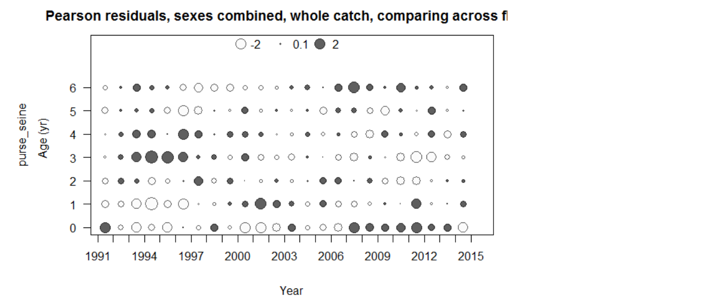
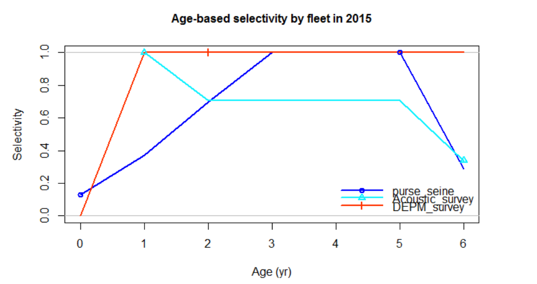
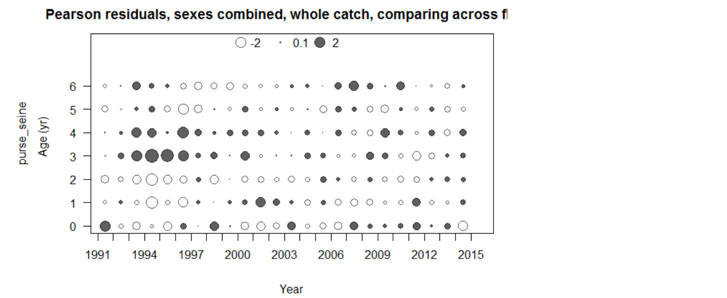
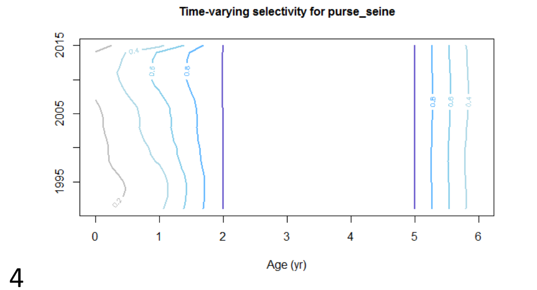
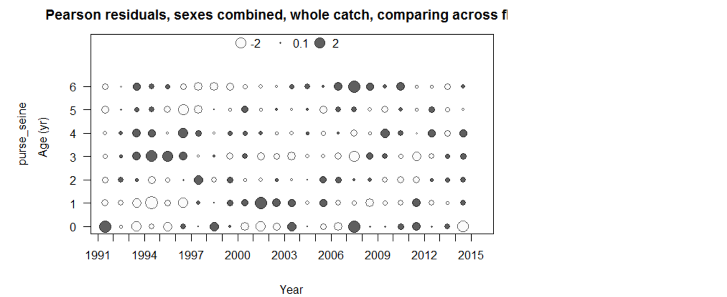
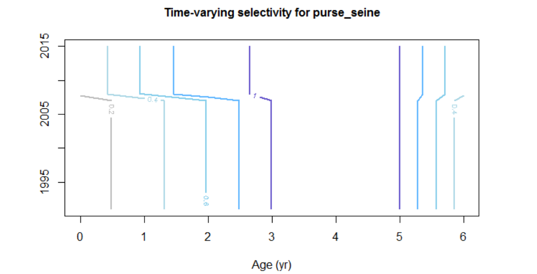
Early R deviations Model		
Random walk selectivity model		 4
2 period selectivity model (1991-2007, 2008-2014)		

Figure 8 - Residuals and selectivity patterns for fishery age compositions of models assuming constant selectivity over time (Early R deviations model), selectivity changing over the entire assessment period as a random walk and selectivity changing from 1991-2007 to 2008-2014.

Conclusions

- In this working document we modelled a shorter historical period (1991-2015) than the period modelled in the current assessment (1978-2015). The period 1991-2015 is data-rich compared to the earlier period as survey data is available only since 1996. Part of the results obtained here may be different if the period 1978-2015 is considered and additional issues may appear;
- The early recruitment deviations model avoided the subjective choice of assuming an initial equilibrium catch providing a more robust fit to the data;
- The inclusion of a stock-recruitment model assuming density-dependent recruitment improved the estimation of recruitment variability, namely at low stock sizes as observed in recent years;
- Models considering changes in selectivity over time improve the fit of the model to catch composition in recent years. Additional trials assuming a gradual change could be considered for future work.

Other issues identified in sardine assessment modelling need to be addressed in future work, such as survey catchability and selectivity at age in catches and surveys. The use of the two surveys, DEPM and acoustics, also needs to be reviewed. Conflicting signals in the DEPM and acoustic surveys were shown in WGHANSA 2015 to be the main cause of the retrospective error seen in the assessment. Although the signal from the two surveys is, at present, more consistent, the possibility that conflicting signals re-appear cannot be excluded.

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